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# MEASURED PERFORMANCE OF A 3-TON LiBr ABSORPTION WATER CHILLER AND ITS EFFECT ON COOLING SYSTEM OPERATION

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# MEASURED PERFORMANCE OF A 3-TON LiBr ABSORPTION WATER CHILLER AND ITS EFFECT ON COOLING SYSTEM OPERATION

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## ABSTRACT

A 3-ton lithium bromide absorption water chiller was tested for a number of conditions involving hot-water input, chilled water, and the cooling water. The primary influences on chiller capacity were the hot water inlet temperature and the cooling water inlet temperature. One combination of these two parameters extended the output to as much as 125% of design capacity, but no combination could lower the capacity to below 60% of design.

A cooling system was conceptually designed so that it could provide several modes of operation. Such flexibility is needed for any solar cooling system to be able to accommodate the varying solar energy collection and the varying building demand.

It is concluded that a 3-ton absorption water chiller with the kind of performance that was measured can be incorporated into a cooling system such as that proposed, to provide efficient cooling over the specified ranges of operating conditions.

## INTRODUCTION

NASA Lewis has been conducting research on solar heating and cooling systems and components. In addition to performance tests of components such as on flat-plate collectors (refs. 1 to 4), the testing of complete systems incorporating such components is essential for an overall solar heating and cooling system evaluation. A laboratory-scale solar heating and cooling system has been built and operated to provide an experimental means for such an overall evaluation (ref. 5). At the present stage of the experimental system design, no differentiation has been made as to whether the building demand is a heating load or a cooling load. In either case, the demand results in a transfer of heat energy out of the system.

Solar cooling has been receiving increased attention over the past year. A recent study (ref. 6) indicates that combined solar heating and cooling systems have greater economic attractiveness than heating only systems (ref. 7). Also, greater attention has been directed to solar applications in commercial buildings, where cooling is normally the pre-

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dominant building energy demand.

Solar cooling can be complex and requires study and tests prior to integration into actual systems. Currently the only type of solar cooling machine commercially available is a lithium bromide-water absorption type modified to operate at flat-plate solar collector temperatures. The particular unit under discussion in this paper is a 3-ton cooling capacity water chiller. The unit was operated in a test loop under the following parameters and values to determine performance:

Hot water source flow rate, gpm . . . . . . . . . . 8, 9.5, 11
Hot water source inlet temperature, $^{\circ}F$. . . . . 216, 220, 224
Cooling water inlet temperature, $^{\circ}F$ . . . . . . . . 75, 80, 85
Chilled water inlet temperature, $^{\circ}F$ . . . . . . . . 50, 54, 58

## DESCRIPTION OF CHILLER TEST SYSTEM

A system was designed to perform a component test on the LiBr absorption water chiller.

### Overall Test System

Testing the performance of the chiller involved controlling the flow rate and inlet temperature of the hot water heat source, cooling water, and the chilled water. The flow schematic is shown in figure 1; the components and apparatus in figure 2. Steam provided the heat source for the hot water supply of the chiller. A controller automatically adjusted the steam flow rate so that the hot water could be maintained at the manually set temperature. The cooling water temperature was controlled by recirculating some of the heated water back to the inlet. The chilled water inlet temperature was controlled by a combination chilled water storage tank and a heater. The tank served to store the cold water discharge while the upper (and warmer) region of the tank was heated as necessary to control the water temperature entering the chiller.

### Absorption Water Chiller

The solar absorption water chiller operates very much like the conventional gas air conditioner (fig. 3) except that the gas heat is replaced by water that is heated by solar energy, and where the output is chilled water instead of cooled air. The operation is sufficiently similar so that an existing gas air conditioner could be modified for our use. Besides the modification involved in the heat input and the water output, modifications were also made to the strength of the LiBr-water solution. This was required to compensate for the additional thermal barrier - the chilled water loop - between the cooling coil and the building heat exchanger.

Briefly, the absorption cycle (fig. 3) involves a heat source that serves (1) to separate the water vapor (the refrigerant fluid) from the LiBr-water solution and (2) to promote slug flow in the vertical tube and thereby "pump" the liquid. The water vapor is liquefied in the condenser and vaporized in the cooling coil. It is the heat exchange during vaporization that the "air conditioning" or the water chilling takes place. The vaporized water is recombined with the LiBr solution in the absorber and the original solution returns to the generator to be cycled again. The external cooling water functions in both the absorber and the condenser parts of the cycle.

A more detailed description of the absorption cooling operation can be found in reference 8.

## TEST PROCEDURE

Each of the four parameters (inlet temperature to the chiller of the hot water, cooling water, and chilled water, and the hot water flow rate) were varied. Using three operating points for each parameter, data were obtained at 81 operating points. It was recognized that at some conditions there would be a danger of simmering and thereby crystallizing the lithium bromide. Such conditions were approached cautiously, and indeed there were 9 conditions that could not be stabilized. These points occurred for the three flow rates and three chilled water temperatures at the low hot water temperature 216° F and at the highest cooling water temperature 85° F. All remaining 72 points were obtained with no difficulty.

At the beginning of each day's test, a data point was taken at one set of conditions:

| | |
|---|---|
| Hot water flow rate, gpm . . . . . . . . . . | 11 |
| Hot water inlet temperature, °F. . . . . . . | 224 |
| Cooling water inlet temperature, °F. . . . | 85 |
| Chilled water inlet temperature, °F . . . . | 58 |

This test point served as the reference chiller output for the data taken that day.

## TEST RESULTS

The results of the test are shown as performance curves in figure 4. The curves are presented on coordinates of hot water temperature flowing to the water chiller and of the percentage output of the design capacity. The design capacity is the cooling accomplished on the chilled water and is referenced to the test point obtained by operating at design conditions.

The primary influences on the output capacity of the chiller were the hot water inlet temperature and the cooling water temperature. The hot water flow rate and the chilled water inlet temperature to the chiller had secondary effects. For a given cooling water inlet temperature, the chiller varied approximately 25 percentage points for an $8^{o}$ change of the hot water inlet temperature. For a unit designed for 36 000 Btu/hr, an $8^{o}$ drop means a decrease in cooling capacity down to 27 000 Btu/hr. The cooling water temperature was quite significant in affecting the chiller capacity. A change of $5^{o}$ resulted in a 15-percentage point change in the chiller output.

The hot water inlet temperature ranged from the design point of $224^{o}$ to $216^{o}$ F. This minimum temperature was that recommended by the manufacturer to prevent the LiBr solidification by simmering. Simmering is that condition in which the water vapor separates from the LiBr solution but where the vigorous boiling required for liquid lift operation is absent. With continuous vaporization without "pumping," the solution would eventually crystallize. However, the hot water temperature was carefully controlled below $216^{o}$ F to obtain the actual minimum temperatures. This was found to be a function of cooling water temperature - that the colder temperatures enabled lower hot water temperatures. At $85^{o}$ F cooling water inlet temperature, the hot water was lowered to $210^{o}$ F and still was operating stably. At $80^{o}$ F cooling water temperature, the hot water was lowered to $206^{o}$ F, and at $75^{o}$ F cooling water temperature, the hot water was lowered to $202^{o}$ F. The minimum $\Delta T$ between the hot water and the cooling water averaged $126^{o}$. In each of these cases, the output associated with the minimum temperatures was approximately constant at 63% of design.

The coefficient of performance (COP), which remained approximately constant at 0.65 while operating within the prescribed conditions, increased to approximately 0.73 at the minimum hot water temperature points.

The COP values obtained verify other findings that this type of 3-ton machine operates at lower COP's than do larger industrial chillers. The main reason is the use of the hot water energy for the liquid lift "pumping" in the small unit. The large industrial units utilize pumps to drive the liquid; the heat energy utilized solely for the separation of the water vapor from the solution. Secondary effects of using a pump is the higher liquid solution pressures that permit a more effective spray operation in the absorber. Incorporation of a pump for the 3-ton unit, which is being developed, should help in increasing the efficiency - the COP - of the small unit.

## DISCUSSION OF RESULTS

The performance curves indicate that the range of hot water temperature over which the chiller can operate depends upon the cooling water inlet temperature. In no case, however, does the minimum output drop be-

low 63% of design. The lower cooling water temperatures extend output above the design point to as much as 125% of design, but extend to the same minimum 63% as the higher cooling water temperatures.

Where the building load requires cooling below the chiller minimum output point, two alternatives are possible. One mode of operation is that of directly coupling the chiller to the building load and operating full-on or full-off. The cyclic operation is inefficient, however, because of the thermal inertia of the system.

A more desirable mode of operation is that of continuous running. To match the chilled water output with building load, one can incorporate a chilled water storage tank. Whenever the chiller output exceeds the building load, the chilled water output can be divided between the load and the tank. This mode is shown in figure 5. The flow circuit also accommodates other modes of operation. When the tank water is chilled, flow can be circulated between the tank and the load (fig. 6). If hot water to the chiller (from the collectors and/or heat storage tank) is available and there is no building load demand, the chiller output can be stored in the tank (fig. 7). On those occasions, expected to be rare, when the chiller output can be matched with the load demand, there can be a direct exchange between the chiller and the load (fig. 8).

The cooling subsystem described integrates the particular characteristics of the chiller into a flexible mode of operation required of a solar heating and cooling system.

## CONCLUDING REMARKS

A 3-ton lithium bromide absorption water chiller was tested over a range of conditions of hot water input, chilled water output, and the cooling water. The primary influences on chiller capacity were the hot water inlet temperature and the cooling water inlet temperature. No combination of parameters, however, permitted operation of the chiller below 60% of design capacity. This limitation is in contrast to larger absorption units which can operate below this point.

This chiller is but one component, albeit a very important one, of a solar cooling system. A cooling system was conceptually designed so that it could provide several modes of operation. Such flexibility is needed for any solar cooling system to be able to accommodate the varying solar energy collection and the varying building demand.

It appears that a 3-ton absorption water chiller with the kind of performance measured can be incorporated into a cooling system such as that proposed to provide efficient cooling over the specified ranges of operating conditions.

## REFERENCES

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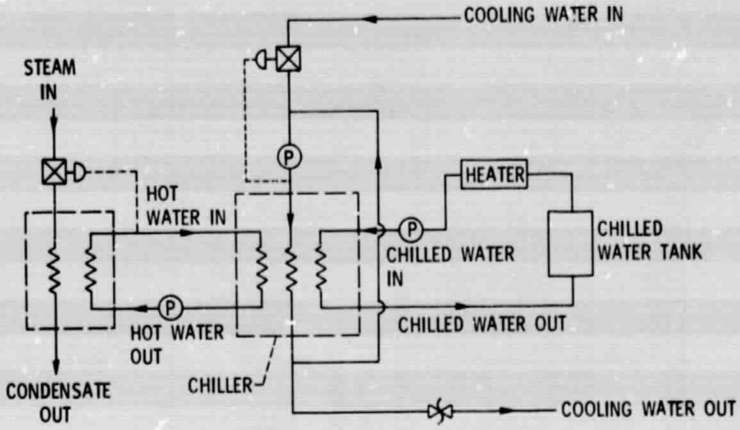


Figure 1. - Flow schematic of chiller performance test.

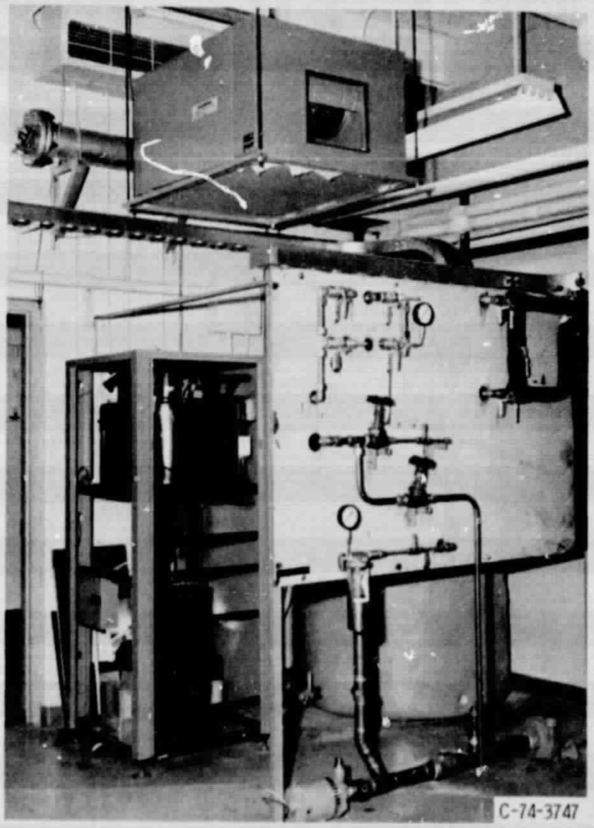


Figure 2. - System for testing LiBr absorption water chiller.

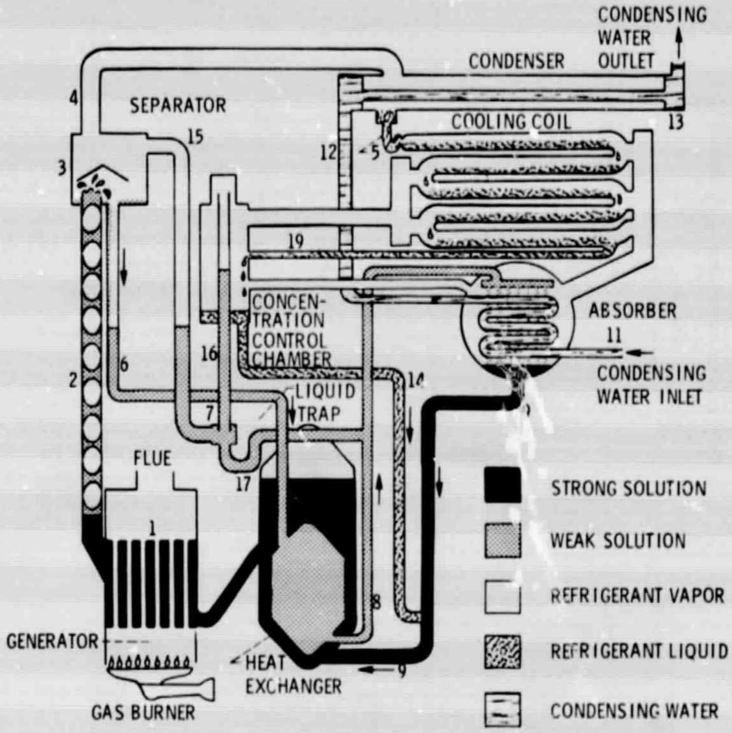


Figure 3. - Diagram of an Arkla lithium bromide-water absorption cooler.

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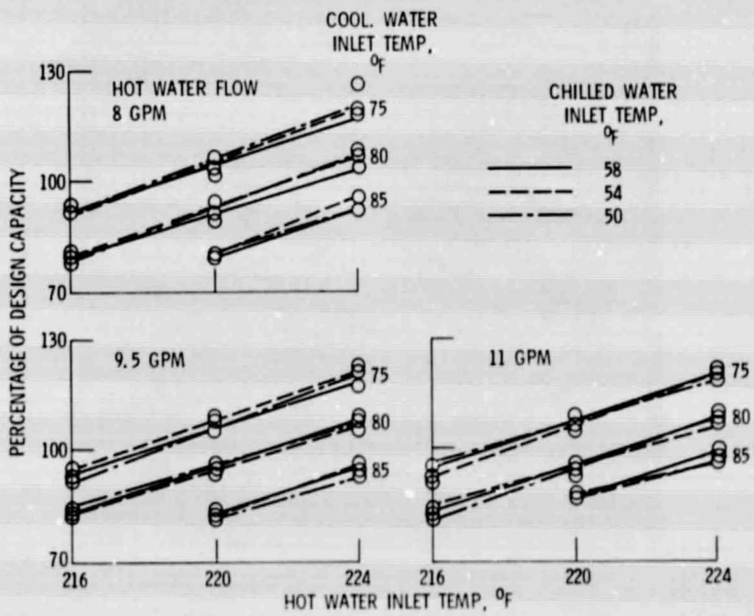


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Figure 4. - Performance of 3-ton LiBr water chiller.

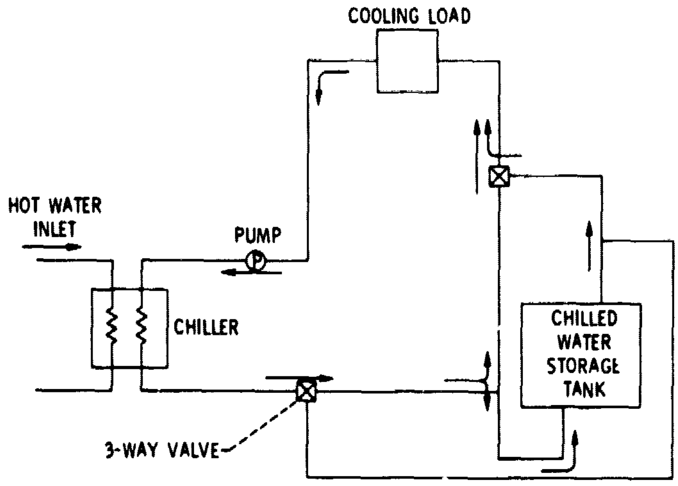

Figure 5. - Cooling sub-system - chiller to tank and load.

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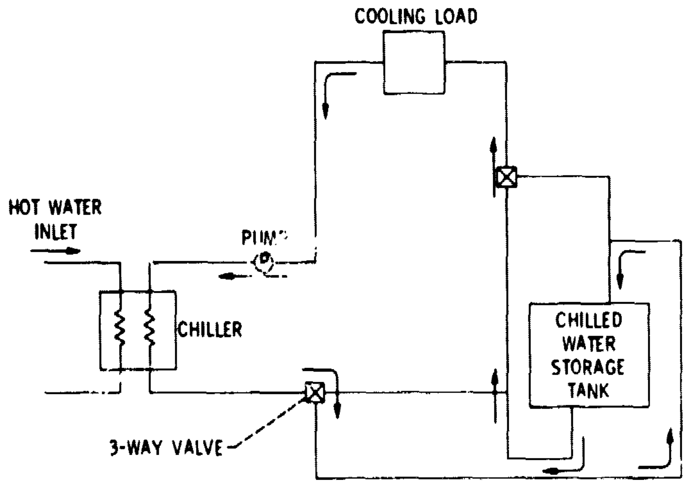

Figure 6. - Cooling sub-system - tank to load.

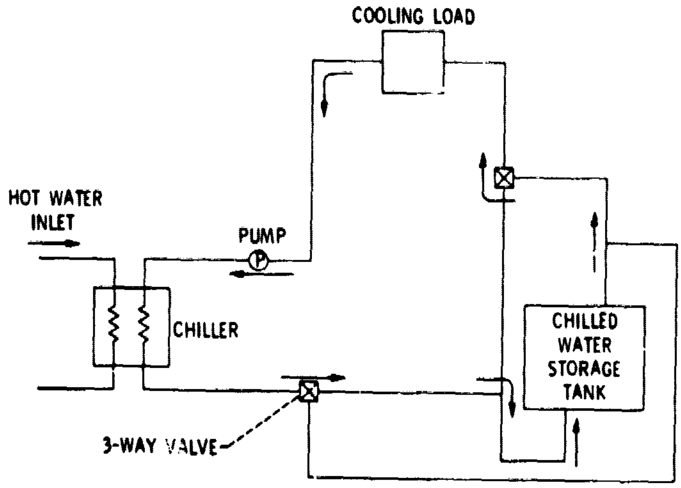


Figure 7. - Cooling sub-system - chiller to tank.

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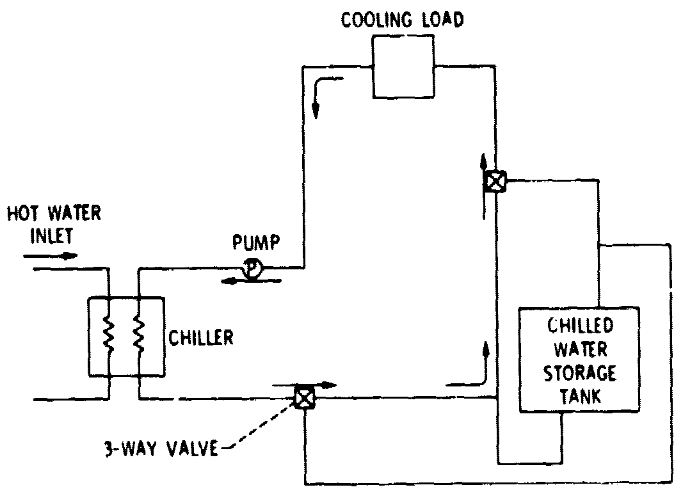


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Figure 8. - Cooling sub-system - chiller to load.